MDE Product Development Team
(Based on Work Plan for 12-month Period from 1 April 2014 through 31 March 2015)
FY14 4th Quarter Report
Submitted 15 October 2014

With contributions from Geoff DiMego and Mary Hart (NCEP/EMC);
Stan Benjamin, John Brown, Steve Weygandt and Curtis Alexander (NOAA/ESRL/GSD);
Jordan Powers (NCAR/MMM); Roy Rasmussen and Greg Thompson (NCAR/RAL);
and Ming Xue (CAPS).

(Compiled and edited by S. Benjamin and B. Johnson)

Executive Summary

Task 1: Improve Turbulence Guidance From NWP Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE

- Operational RAPv2 continues to run reliably at NCEP, now completing in September its first full summer period since RAPv2 implementation back in Feb 2014. Some warm and dry bias near the surface was evident in RAPv2 this summer but improvements for it are already in the pipeline from GSD; NCEP version lags by about a year.
- Real-time experiments for the 2014 warm-season exercise continued with advanced experimental RAPv3 and HRRR code, frozen since April 2014 and with improvements over NCEP RAPv2. RAPv3/HRRRv2 real-time code will be updated this fall -- further model and assimilation changes not yet added to frozen code appear very effective to largely eliminate daytime warm-season warm/dry bias. These include better use of surface observations and physics changes reported under Task 3.
- RAPv3/HRRRv2 implementation at NCEP is planned for summer 2015.
- Development and testing continuing of initial pre-NARRE 8-member ensemble (4-NMMB, 4-ARW), July retrospective experiments show yet better reliability.
- NAMv3.1 was implemented into NCEP operations on 12 August 2014.

Task 2: Improve Quality Of Convective Weather Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE and HRRRE

- 3-km HRRR successfully implemented operationally at NCEP on 30 Sept 2014, a culmination of long-term support by FAA/AWRP with NOAA operational modeling. (Key collaborating organizations with GSD: NCEP/EMC, NCEP/NCO, NCAR (WRF/ARW).)
- Ongoing testing and evaluation of code refinements for HRRRv2, with emphasis on reducing warm, dry bias and upgrading to WRFv3.6+ for the model component.
- Tests of new data assimilation code for radar reflectivity observation-based hydrometeor specification (full column for all temperatures when reflectivity ≤ 28 dBZ) indicating improvement in short range precipitation prediction. These changes will be likely be implemented in the real-time experimental RAP and HRRR runs by November.

Task 3: Improve Quality Of Icing Weather Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE

- Summary of physics changes in real-time and retrospective testing for advanced RAPv3 include those in land-surface model (snow treatment, sub-grid mosaic, wilting point), PBL scheme (shallow cumulus, effective sub-grid clouds and radiation), cloud microphysics (aerosol-aware), improved radiation effects, lake model, modified Grell-Freitas, RRTMG radiation.
- Aerosol-aware microphysics scheme from NCAR (Greg Thompson) within WRFv3.6 is running in a RAP parallel cycle with overall favorable results, but evaluation has identified matters for further attention.
- Initial tests also made within RAP of improved lake surface temperatures through WRF CLM (Community Land Model) lake model, another new option available within WRFv3.6.
- Extensive set of the physics changes as of April 2014, along with data assimilation and other model improvements to both the RAP and HRRR forecast systems, were implemented for the 2014 warm season evaluation as summarized in the following report: **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf**.

Task 4: Develop Convection-ATM-Specific Improvements To Guidance From the HRRR (and later, HRRRE) And, Interact With CoSPA (Or Other) Program Partner Labs And The FAA

- Discussion with CoSPA users continued regarding NCEP HRRR implementation details including improvements in timing of gridded forecast delivery (reduced latency) and other differences between ESRL and NCEP HRRRs.
- GSD froze all data assimilation and model changes for ESRL RAPv3/HRRRv2 as of 10 April 2014 on Jet and Zeus. The ESRL RAPv3/HRRRv2 changes will be implemented at NCEP in summer 2015.

- Testing of 3km-HRRR with WRFv3.6+ with WRF changes to GSD-developed model physics and assimilation has started.
- The real-time frozen ESRL RAPv3/HRRRv2 system continues to run with gridded field dissemination during the CoSPA season that began on 17 April 2014 and soon ending on 31 October 2014.
- ESRL HRRR "failover" capability to use feed from Zeus instead of Jet during Jet downtime continues to work effectively for CoSPA.
- ESRL HRRR output format changes for alignment with the NCEP HRRR operational implementation will be coordinated with COSPA program partner labs after 01 November 2014.
- Initial discussion with MIT/LL occurred in July regarding a capability to provide hourly updated vertically integrated liquid and echo top estimates from the ESRL RAP for oceanic regions outside of the HRRR domain.
- Initial discussion with AvMet to plan a meeting discussion for measuring potential operational ATM benefits gains associated with HRRR forecast enhancements.
- The HRRR was implemented operationally at NCEP on 30 September 2014.

Task 1: Improve Turbulence Guidance From NWP Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE

Improving turbulence forecast quality involves efforts to improve initial conditions for the RAP and NAM (and HRRR and NAM Nest models) and to improve the models (WRF-Advanced Research WRF (ARW)-RAP and NOAA Environmental Modeling System (NEMS)- Nonhydrostatic Multi-scale Model – B (NMMB)).
Tasks will include:

- Continuing evaluation of RAPv3 toward 2015 implementation at NCEP, incorporating changes developed in 2013 and 2014.
- Development of RAPv4 toward 2016 implementation at ESRL and subsequent implementation at NCEP. (Note, some improvements from RAPv4 will be thoroughly tested in all seasons and included in the RAPv3/HRRRv2 package for NCEP.)
- Collaborating on developing and testing best approaches for use of hybrid/EnKF/3DVAR data assimilation within common GSI coding structure.

ESRL

Regarding the operational NCEP RAP (currently RAPv2)

The RAPv2 continues to run well in NCEP operations, without any model or post-processing issues during the July-September 2014 quarter. The RAP web page **http://rapidrefresh.noaa.gov** has information on the operational RAPv2 configuration including a February 2014 NWS webinar ppt on RAPv2 **- http://ruc.noaa.gov/pdf/RAPv2-NWSwebinar-18feb2014-FINAL.pdf**. A link to the RAPv2 Technical Implementation Notice is also available on the RAP web page. A webpage on RAP output grids from NCEP is at **http://ruc.noaa.gov/rr/RAP-NCEP-output-grids.html**.

RAPv3 model testing and evaluation

The preliminary RAPv3 configuration of 5 April 2014 continues to run reliably in the RAP-primary cycle at GSD. This cycle continues to drive the HRRR-primary running at GSD in support of the 2014 warm-season exercise. This cycle remains frozen through 31 October 2014. A summary of the upgrades from RAPv2 going to RAPv3 (and HRRRv2) has been published on the web at **http://ruc.noaa.gov/pdf/RAPv3-HRRR-April2014.pdf** with a more detailed description available at **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf**.

The RAPv3 warm-dry bias noted in the FY14 Q2 report has now been largely eliminated. After isolating core issues (discussed further under Task 3), we have developed very effective changes to both assimilation and model to address them. We have conducted and are continuing a thorough evaluation of these changes in two real-time RAP development cycles at GSD (dev2 and dev3), both advanced versions of RAPv3. This evaluation also used extensive retrospective testing and evaluation of candidate changes, using a short mid-June 2014 retrospective period during which the warm-dry bias was particularly egregious. We now think we are close to a configuration that will largely alleviate the bias through a combination of model changes, discussed under Task 3, but also with a few changes in how we determine the observation innovations for the analysis.

Because of the requirement to have RAPv2 code ready for transfer to NCEP by later this fall (Task 1 deliverable E4), and in order to stay reasonably current with the latest WRF-ARW version release by NCAR, contrary to our practice in previous years, we could not wait for the August release of WRFv3.6.1. We have been working with an NCAR WRF repository version from early June we are calling WRFv3.6+. This version has several important bug fixes from the original WRFv3.6 release in April. Since completion of the merger of WRFv3.6+ with GSD enhancements not yet in the WRF

repository, we have been running this merged code in RAP-dev3, as well as evaluating its performance for retrospective periods from other seasons. The most important difference between this v3.6+ version and the WRFv3.5.1 currently running in the RAP-primary cycle is availability of the NCAR-Thompson aerosol-aware microphysics, but we have also been moving the more certain dev2 changes from the RAP-primary into dev3. Evaluation of this new microphysics package continues (see Task 3).

Key GSI data assimilation changes developed and evaluated during the quarter for RAPv3/HRRRv2 include and use of model-derived low-level temperature and moisture directly at 2m (where observations are usually made) instead of at the lowest model level or any interpolated value. This includes an improved diagnostic for the 2-m water vapor mixing ratio. Discussion has also started on improved cloud assimilation from use of an estimated cloud fraction from the model (from MYNN PBL scheme development – see Task 3) allowing more direct use of METAR-reported cloud fraction (broken, scattered, etc.).

NARRE-related activities

GSD (Isidora Jankov) continues to refine a very promising set of experiments using a preliminary ensemble configuration including both ARW and NMMB models toward the North American Rapid Refresh Ensemble (NARRE). Additional interoperable physics options for both ARW and NMMB are now being used in our NARRE testing. Real-time testing of a preliminary NARRE ensemble at ~13km resolution is planned to start by 15 November. In July, GSD personnel involved in NARRE development met at GSD with Jacob Carley of NCEP to exchange ideas and outline future options and directions for NARRE development. This will include integrating the NAMRR (also toward NARRE) now under development at NCEP.

Initializing the NARRE forecast ensemble will most likely use a regional ensemble data assimilation cycle (allowing improved cloud/radar initialization over current use GFS ensemble-based covariance). Different physics configurations or possibly stochastic versions of key physics parameterizations will be used for different NARRE members. Stan Benjamin and Geoff DiMego have completed a draft report outlining the development, test and evaluation tasks needed over the next year or two to bring NARRE to fruition and how these will be partitioned between GSD and NCEP.

Subtasks

14.5.1.1 Ongoing **(NCEP, GSD)**
Maintain hourly RAP and HRRR runs and provide grids of SAV and AHP guidance products.

GSD: GSD has continued to monitor real-time-NCEP output from the RAP and pre-operational HRRR, now continuing as the operational HRRR implemented at NCEP at 1400 UTC 30 Sep.

NCEP: A job was added to dump WSR-88D L2 radial winds at T+16 each hour (10 minutes earlier than the production cutoff time of T+26) and post the dump files to ftpprd server as requested by GSD. This change will reduce latency for radial wind data, now allowing improved testing of radial wind assimilation in RAP and HRRR toward possible implementation at NCEP in 2015.

There were no issues with the RAP in the 4th quarter. The HRRR became operational on 30 September; it is also covered in 14.5.2.E1. (Manikin, Keyser)

NCEP: There were no issues with the RAP in August. The HRRR is not yet operational, it is covered in 14.5.2.E1. (Manikin, Keyser)

14.5.1.2 28 July 2014 **(NCEP, ESRL & CAPS)**
Groups collaborate on developing and testing best approaches for use of hybrid/ EnKF/3DVAR and 4d-ens-var within common GSI coding structure.

ESRL

GSD: (Ming Hu) continues to prepare a new GSI/model repository from which MDE research partners (GSD, EMC, CAPS, OU, others) will check out common software for regional ensemble data assimilation development toward NARRE.

NCEP: the NCEP and GSD developers gave Lectures on radar data assimilation and the GSI data assimilation system at the July GSI Tutorial in Boulder. No activity in August or September. (Carley, Wu, Parrish)

14.5.1.3 30 Sept 2014 **(CAPS, GSD, EMC)**
Test and evaluate direct radial velocity and reflectivity data assimilation within the 40-20km/13km dual resolution hybrid system. (Resolution dependent on computing resources)

CAPS

In September, the testing of the direct assimilation of radar reflectivity in GSI system continued at CAPS. The background error covariances for mixing ratios of cloud and hydrometers make use of the error covariance structure of water vapor as the first step. Flow-dependent error covariance is derived from the 40-km ensemble. Single time analyses have been performed and initial results are reasonable. Most of this work was proposed under plan B for FY2014, which was not funded; therefore, progress will be limited.

EMC

July: The evolution of the temperature tendencies before and after the digital filter initialization in NAMRR using a RAP-developed technique was checked to confirm that the filter was behaving correctly. Other forecast fields were also scrutinized. No activity in August or September. (Liu, Carley)

14.5.1.4 1 Jan 2015 **(ESRL, CAPS)**
Test the 40/13 km dual-resolution system with hourly DA cycles including all observation types, including radar reflectivity data via cloud analysis and DDFI.

14.5.1.5 28 Feb 2015 **(NCEP, ESRL & NCAR)**
Groups collaborate on developing and testing physics schemes between WRF and NEMS' physics layer.

GSD

GSD continued to expand interoperable physics options for NARRE using ARW and NMMB. It also refined preliminary NARRE configuration testing ARW with RAP and NAM-like physics and also with NMMB using NAM physics, and will next expand the NMMB options to include the Thompson MP (microphysics) scheme and RUC land-surface model.

NCEP

Studies were done on cases where the NMMB failed to develop deep convection (28 April, 11 May, and 3 June 2014). Runs made at 1 km and 3 km resolution with parameterized shallow convection had either a neutral or positive impact on severe weather forecasts for all three cases. Another study was done on a case (3 August 2014) where the model produced an unrealistically large single-grid point maximum of accumulated precipitation. In the tests the location of the grid-point maximum changed and was not duplicated in any runs, so a different approach should be taken to address this issue. Work continues on scripts to plot vertical cross sections from various NAM domains (for evaluating model forecasts), with a particular focus this past month on displaying various cloud hydrometeor fields. Sensitivity experiments tested the impact of using a new set of shortwave radiation tables associated with the radiation model recently incorporated into the WRF v3.6.1. Three different cases were tested in 12-km NMMB Launcher experiments, and each showed only tiny impacts from using the new radiation on precipitation, surface, and upper-air verification scores.
In September, the new BMJ shallow convection scheme was tested against the current version. The new scheme tended to suppress convection too much in some cases. Work continued on the vertical cross-section plots and a new script improved the depictions of the cloud base and top heights and pressures. The completed code for the Thompson microphysics with the optimized RRTM version 3-radiation driver was tested but wouldn't compile when enhanced run-time error checks were used. A fix for this problem was coded and is being tested. (Ferrier, Aligo, Jovic)

14.5.1.6 28 Feb 2015 **(NCEP)**
Complete testing of improved or extended 88D processing and quality control, taking advantage of dual-pol where possible.

Code (with updates) for the 3-D radar mosaic processing was put into NCEP's vertical structure and submitted to NCO for implementation as part of the ObsProc update. (Liu)

14.5.1.7 15 Mar 2015 **(ESRL, CAPS, NCEP)**
Complete readying of initial regional ensemble data assimilation capability to initialize real-time parallel RAP version and NAMRR.

GSD

Ming Hu has conducted key experiments in varying horizontal and vertical localization in the ensemble/hybrid data assimilation used for RAP. It was found that the current hybrid (ensemble/variation) fraction now used in RAPv3 (0.75) is preferable to 1.0 or 0.5 for the span of 3h-18h forecasts for the RAP. It was also found out that the current localization values appear to be best, although additional experiments are expected.

NCEP

After integrating the system tools into GSI, it was found that the memory problem was because of a big matrix used for spectral to grid transform. One alternative is to calculate the matrix only when needed but that still uses significant CPU resources. The agreed upon solution is to truncate the global ensemble files before they are used by the operational NDAS [and RAP] system. A copy of the NCEP NMMB modeling system was provided to the University of Oklahoma to assist with their development of a hybrid ensemble variational method for assimilating radar data into the NMMB model using the GSI. (Carley, Wu, Rogers, Parrish)

14.5.1.8 28 Mar 2015 **(NCEP and ESRL)**
Negotiate Data Mining List priorities with NCEP Central Operations and external points of contact associated with the most desirable new sources of observations.

NCEP

No new items were requested this quarter so Data Mining List remained unchanged. Outside of the DML, GOES imager obs have been identified as necessary & critical to the cloud cover analysis being added to RTMA/URMA in FY15Q2. Ingest of these data will be handled by EMC (not NCO Data Flow) and work on this task has begun. (Keyser, Whiting)

GSD

New agreements with energy companies for use of their proprietary tower and nacelle wind data were drafted in May by GSD and coordinated with NWS. This proprietary wind data is already on the DML.

14.5.1.9 31 March 2015 **(NCEP)**
Establish a pre-implementation version of the hourly updated NAMRR with a goal to use the common regional ensemble data assimilation.

The latest improvements to the NAMRR were committed to the repository in August. Retrospective NAMRR runs for the latter half of May 2013 (for multiple severe weather events) was completed. Another series of NAMRR runs for 28 April, 11 May and 3 June 2014 were started to test the impact of including parameterized shallow convection in the 3-km CONUS nest domain.

In September all the NAMRR codes were committed to the repository and the DTC was given instructions on how to run the NAMRR. Retrospective runs to test the impact of the shallow BMJ convection were completed for May 2013. (Carley)

Deliverables

All Option A unless noted otherwise.

14.5.1.E1 10 April 2014 **(ESRL)**
Finalize RAPv3 and HRRRv2 for summer 2014 real-time exercise.

COMPLETE. A summary of the spring 2004 RAPv3 and HRRR v2 configurations has been published on the web at **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf**

14.5.1.E2 31 May 2014 **(NCEP)**
With approval of NCEP Director, NAMv3.1 upgrade package is implemented at NCEP.

The NAMv3.1 evaluation ended on July 30th, the NCEP director was briefed August 8th and the NAMv3.1 was implemented on August 12th. (Rogers)

14.5.1.E3 30 July 2014 **(NCAR/MMM)**
Deliver a WRF Users' Workshop and a WRF tutorial for the user community.

As previously reported, NCAR held the 2014 WRF Users' Workshop June 23–27. NCAR/MMM also conducted a basic WRF tutorial July 21–July 25, with 60 participants. The tutorial covered model processors and utilities, configuration, and operation. Practice sessions allowed participants to run various components of the system. The WRF-related tutorials continued through July 28–August 1 with tutorials on WRF data assimilation, regional climate modeling, and WRF-Chem.

PLANNED EFFORTS: NCAR will organize and conduct a WRF tutorial at NCRA January 26–February 5, 2015.

UPDATES TO SCHEDULE: None.

14.5.1.E4 **New date: 15 Jan 2015** (from 20 Oct 2014) **(ESRL)**
Code for RAPv3 and HRRRv2 finalized for transfer to NCEP/EMC for 2015 implementation.

Progress has been steady with testing having started with WRFv3.6, earlier in the year than GSD has done previously with the annual WRF release. Merger of WRFv3.6+ with RAP / HRRR enhancements was completed in July and the RAP-dev3 cycle is now running WRFv3.6+ with the Thompson-Eidhammer aerosol-aware microphysics option turned on and other physics and assimilation improvements developed by GSD. See Task 3 for more physics details.

14.5.1.E4.1 31 Mar 2015 **(ESRL)**
Report on wind accuracy from RAP and HRRR by quarter for previous year, strongly related to turbulence guidance.

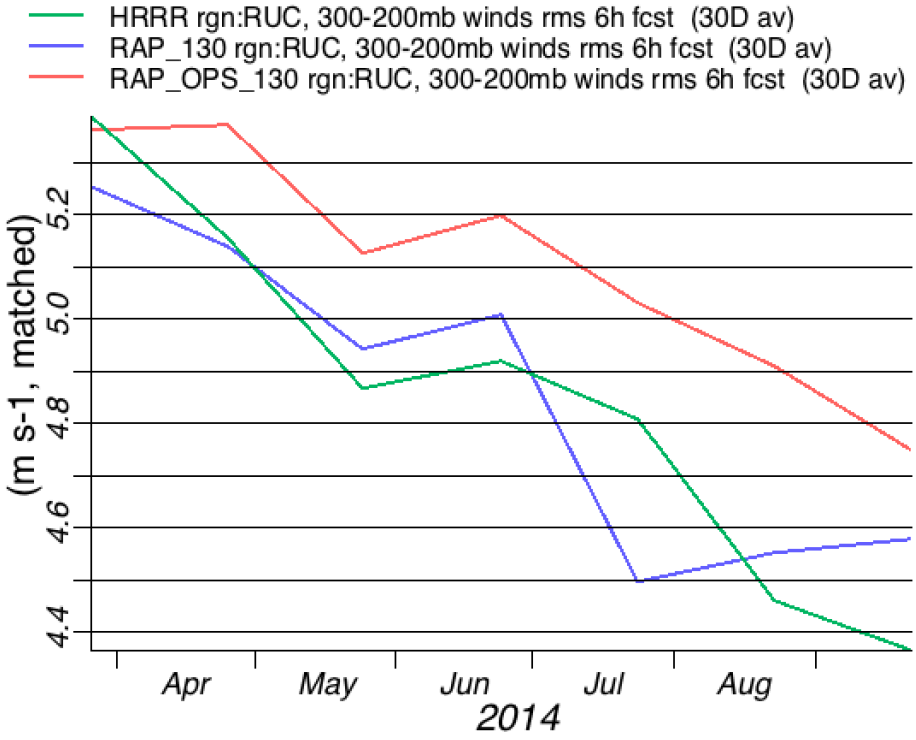

Figure 1: Upper-level (300-200 hPa) wind forecast RMS vector error vs. raobs for 6h forecasts from RAPv3 (ESRL, in blue), RAPv2 (NCEP, in red), and HRRR (ESRL, green). All scores are from native gridded data, not from isobaric coordinate data and show 30-day averages for forecasts from March through September. Units – m/s.

An initial look at upper-level 6h forecast wind accuracy during 2014 (now updated through September) shows relative wind accuracy between the operational RAP (red), ESRL RAP (blue), and ESRL HRRR (green) as shown in Fig. 1. After the introduction of RAPv3 and HRRRv2 in the ESRL runs in early April, those updated versions are showing clearly improved wind forecast skill over that from the NCEP RAP (red). This also implies that turbulence guidance, heavily dependent on upper-level wind forecast accuracy, has also been improved from this update. Therefore, improved wind information to further improve turbulence forecasts is clearly in the pipeline with RAPv3 and HRRRv2 to be implemented at NCEP in mid-2015.

Details on the RAP-HRRR updates in early April 2014 are described in http://ruc.noaa.gov/pdf/RAPv3-HRRR-April2014.pdf and **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf.** Verification against aircraft observations

is also shown in Fig. 2 but only for the ESRL RAP (changing from RAPv2 to RAPv3 in early April). In future months, results from the NCEP RAP and HRRR models will be added to allow comparison for winds vs. aircraft observations.

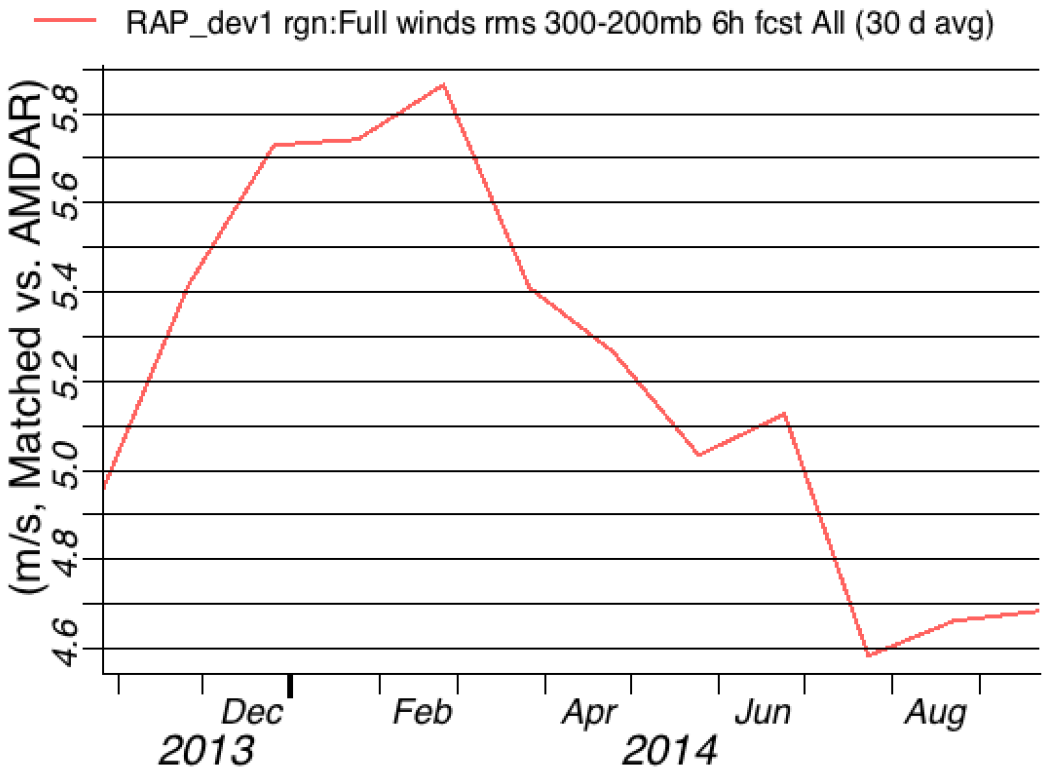

Figure 2: Upper-level (300-200 hPa) wind forecast RMS vector error vs. aircraft for 6h forecasts from the ESRL experimental RAP (RAPv2 through March 2014, RAPv3 since then. Units – m/s.

14.5.1.E5 31 Oct 2014 **(ESRL, CAPS, NCEP)**
Complete the testing of the 40-20/13 km dual-resolution hybrid DA system for RAP with 3-hourly cycles with conventional data.

CAPS

Most efforts at CAPS were spent on testing the reflectivity assimilation capabilities in GSI in September. Funding to CAPS for FY13 and FY14 has not arrived so CAPS was working on project with its own funding. However, plan in this area is planned and will proceed based on discussions with GSD.

NCEP
The NAMRR development work in 14.5.1.9 is a precursor to this work. (Carley)

GSD

GSD has tested localization options for the GFS-ensemble-based covariances for the 40km hybrid DA system for RAP. GSD is also setting up a GSI repository for use for common GSD-NCEP-CAPS experimentation for hybrid ensemble data assimilation development.

14.5.1.E6 20 Dec 2014 **(ESRL)**
Report on RAPv3 model and data assimilation configuration and progress. This will include a report on wind verification and its improvements in RAPv3 vs. RAPv2.

14.5.1.E7 New date: 15 Jan 2015 **(ESRL and NCEP)**
Finalize code for RAPv3 to NCO for implementation at NCEP.

NCEP

The RAPv3 code being tested by ESRL will not be given to EMC until after the HRRR implementation in September. (Manikin)

GSD

GSD is carefully evaluating RAPv3 performance as described in the general information under Task 1 above. A set of further changes anticipated as possible for fall changes to the ESRL RAP code before transfer to NCEP for the final NCEP-RAPv3 configuration has been established. This set includes WRFv3.6, aerosol-aware microphysics, improved coupling between parameterized shallow convection and short-wave radiation, and improvements to GSI data assimilation including treatment of surface observations and assimilation of cloud and radar data.

14.5.1.E8 31 Jan 2015 **(ESRL, NCEP)**
Pending NCEP computer readiness and EMC and NCEP initial recommendations, Requests for Change (RFCs) are filed to submit code changes as part of upgrade for RAP v3 software to NCO.

NCEP

This work will not begin until after the HRRR implementation in September. (Manikin)

14.5.1.E9 31 March 2015 **(NCAR/MMM)**
Incorporate physics and dynamics improvements into WRF from the user community, GSD, and NCEP for use in the RAP and HRRR. Oversee code preparation and integration of these improvements into the WRF repository for future model version releases and FAA use. Assist in the implementation of bug fixes. In collaboration with GSD, assist in the development and evaluation of physics schemes for the RAP and HRRR that are contributed to the ARW.

NCAR/MMM released WRF Version 3.6.1 on August 14th. This contains a number of improvements and bug fixes. Areas addressed include radiation, microphysics, cumulus schemes, surface physics, dynamics, and software infrastructure. A capability to heighten the model top to allow inclusion of most of the stratosphere was also added. Details on V3.6.1 may be found at: **http://www2.mmm.ucar.edu/wrf/users/wrfv3.6/updates-3.6.1.html**.

Jimy Dudhia (NCAR/MMM) obtained code for stabilizing model diffusion in complex terrain. This was added to the repository and released in WRF V3.6.1. It is represented by diff_opt=2, km_opt=4.

Dudhia worked with Ming Chen (NCAR/MMM) to implement a new lightning index in WRF. This indicates the potential for lightning at grid points and works with microphysics schemes with graupel. This was obtained from Barry Lynn (Hebrew University of Jerusalem, Israel) and was released with V3.6.1.

Dudhia (NCAR/MMM) Dudhia obtained code from Travis Wilson (UCLA) that implements top-down mixing in the YSU PBL scheme to represent processes driven by cloud-top radiative cooling. This will be a switch in the next release, WRF V3.7.

Dudhia consulted with the DTC (Developmental Testbed Center) on enabling the GFS surface/slab model to work with the Noah LSM in WRF. Currently the DTC is seeing surface temperatures and fluxes in simulations that look unrealistic. Dudhia also began work with NCAR/MMM visitor Kjetil Aas (Univ. of Oslo, Norway) on sub-grid snow effects in WRF on soil below and its seasonal behavior.

Dudhia obtained a code fix for urban surface temperature from Mukul Tewari (NCAR/RAL). This decreases a lower limit (implemented to prevent blowups) on the value of the exchange coefficient and works with urban options in WRF. It has been added to the repository.

Dudhia added a fix for the Goddard shortwave scheme's cosine zenith angle computation to the repository. This provides for consistency with diffuse/direct radiation diagnostics. Dudhia also worked with Wei Wang (NCAR/MMM) and Jose Ruiz-Arias (Univ. of Jaen, Spain) to look at cloud-radiation biases in surface solar fluxes in WRF. It has been found that the interaction of convective schemes with radiation, such as the new KF cumulus option, only helps part of this problem. They are testing other ideas now (such as use of RH-based cloud fractions).

Dudhia consulted with NCAR visitor Sebastian Masson of IPSL (Institut Pierre Simon Laplace, France). IPSL is coupling WRF with an ocean model and examining radiation differences between the Dudhia and Goddard shortwave schemes. Dudhia worked with setting up diagnostics for physics tendencies.

PLANNED EFFORTS: The development and incorporation of new physics and dynamics for WRF for the RAP and HRRR will continue into the next quarter.

UPDATES TO SCHEDULE: NONE

14.5.1.E10 31 March 2015 **(ESRL and NCEP)**
Deliver progress report on development of NARRE.

NCEP

No activity in September on NARRE but work on SREF in 14.5.4E2 is closely related. (Du, Zhou, Yang, Jovic)

Deliverables Task 1: Improve Turbulence Guidance From NWP Forecasts	Delivery Schedule
A. Finalize RAPv3 and HRRRv2 for summer 2014 real-time exercise.	APR 2014 COMPLETE
B. Code for RAPv3 and HRRRv2 finalized for transfer to NCEP/EMC for 2015 implementation. Strong progress toward this at GSD through RAPv3/HRRRv2 current real-time evaluation.	New date Dec 2014
C. Complete the testing of the 40-20/13 km dual-resolution hybrid DA system for RAP with 3-hourly cycles with conventional data.	New date Jan 2015
D. Report on RAPv3 model and data assimilation configuration and progress. This will include a report on wind verification and its improvements in RAPv3 vs. RAPv2. Preliminary RAPv3 configuration already available **in http://ruc.noaa.gov/pdf/RAPv3-HRRR-April2014.pdf.**	DEC 2014
E. Finalize code for RAPv3 to NCO for implementation at NCEP.	Modified: JAN 2015
F. Report on wind accuracy from RAP and HRRR by quarter for previous year strongly related to turbulence guidance. Initial evaluation on wind accuracy from RAP and HRRR vs. raobs and aircraft observations has been started and included in this monthly report.	MAR 2015
G. Requests for Change (RFCs) filed to submit code changes as part of upgrade for RAPv3 software to NCO.	MAR 2015
H. Deliver progress report on development of NARRE.	MAR 2015

Task 2: Improve Quality Of Convective Weather Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE

Subtasks

14.5.2.1 15 April 2014 **(GSD)**
Report on enhancements to RAP 13-km and HRRR 3-km radar data assimilation for beginning 2014 warm-season evaluation using the ESRL-updated version of the HRRR (i.e., HRRRv2).

COMPLETE: As reported in the April 2014 MDE report:
Following extensive testing and evaluation, a RAP/HRRR change bundle was made in late March 2014. The package includes changes to both the data assimilation and model portions of both the RAP and HRRR forecast systems and is summarized in the following report: **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf**

(Previously reported for this task for history sake.) The testing involved single-case study experiments, retrospective evaluations, and real-time parallel cycles of individual changes and grouping of changes to check all aspects of the change bundle. The change bundle was a mix of addressing known issues and adding new capabilities. Highlights of the change bundle for the RAP include enhancements to the hybrid data assimilation and the cloud analysis, improvements in the snow cycling and dew point assimilation, and upgrades to the Grell-Freitas (GF) cumulus parameterization and the MYNN planetary bounder layer scheme. Highlights for the HRRR include most of the RAP enhancements plus adding a hybrid assimilation procedure and adjustments to the strength of the reflectivity-based diabatic heating. Also, both the WRF model and GSI analysis were updated to the latest community repository versions.

Statistical evaluation of both the RAP and HRRR retrospective and real-time parallel runs showed broad improvement in nearly all aspects (upper-air, surface, precipitation, reflectivity, etc.). Real-time performance has been good; though evidence of a warm, dry bias has been seen for pre-frontal, southerly flow regions. A variety of aspects related to this are being investigated in off-line, retrospective, and real-time parallel tests, including partial cloudiness, radiation and land surface model issues, and surface temperature assimilation factors. Specific data assimilation changes include creation of pseudo-innovations to the 1h forecast depth of the PBL (planetary boundary layer) for surface temperature observations (similar to the pseudo-innovation created for surface dew point observations) and modification to the forward model for surface temperatures.

14.5.2.2 15 May 2014 (request delay to 1 Dec 2014) **(GSD)**
Improved (optimized weight factors, and observation selection) 15-min HRRR-based RTMA.

Request for delay to 1 Dec 2014.

Background: A key scientist to work on this task left GSD for another position in March. There has been some experimentation done on improved observation selection for the HRRR-based RTMA but more work will be done before the new requested due date. Experiments will also examine the run time for 15-min RTMA analysis with goal of reducing it to near 10 min. A new scientist is in place, but still learning the various systems and components.

14.5.2.3 5 August 2014 **(GSD)**
Complete testing of updated version of 3-km sub-hourly radar assimilation within HRRR pre-forecast cycling period.

We have completed retrospective testing of an enhancement to the radar observation-based rain and snow hydrometeor specification within the HRRR pre-forecast period. The enhancement is to specify rain and snow hydrometeors from radar reflectivity observation throughout the entire column (using observed radar reflectivity for the lighter precipitation range from 15-28 dBZ). Previously, we only did full column building of precipitation hydrometeors from radar reflectivity data when the surface temperature was less then 5C (primarily building snow). When the surface temperature was greater than 5C, only a single layer of precipitation hydrometeors was added (at the level of maximum observed reflectivity). The impact from testing this radar-assimilation enhancement with 15-28 dBZ with warm-season (Tsfc > 5C) surface conditions has been successful, to reduce a low bias in short-term (0-2 hr) prediction of light to moderate precipitation in the warm season.

Additional 3-km radar assimilation work is underway to test and evaluate fully cycled 3-km HRRR runs. Preliminary tests in which the HRRR land-surface fields have been fully cycled (as opposed to just interpolated from the fully cycled RAP land surface model fields) have been successful (reasonable field evolution, indications of improved model performance) This is being followed to experiments with full data assimilation cycling. This testing has been in addition to ongoing work to reduce the afternoon warm and dry bias in the HRRR (see below and task 3).

14.5.2.4 20 Oct 2014 **(GSD)**
Complete 2014 HRRR summer evaluation using modeling and assimilation modifications determined in 2013 exercise. Collaborate on analysis of HRRR tests and deliver summary of results.

The HRRR summer evaluation has indicated expected results (improvements in 2014, clues for next refinements). Retrospective and parallel testing of RAP runs with modifications to reduce the warm/dry bias have yielding encouraging results, which lead to improvements in subsequent nested HRRR runs. These RAP changes are described in more detail under task 3 and have included: 1) the addition of a provision for sub-grid-scale cloud fraction and associated interaction with shortwave radiation and 2) adjustments to the wilting point parameters in the land-surface model, resulting in increased transpiration from the parameterized vegetation. Work is also ongoing to test and evaluate WRFv3.6.1 for RAP and HRRR.

14.5.2.5 15 Dec 2014 **(GSD**)
Based on 2014 RAP and HRRR results, provide update report on development and testing of data assimilation and model enhancements important for improving forecasts of convective weather within the RAP and HRRR.

14.5.2.6 5 Dec 2014 **(GSD)**
Single-case test of storm-scale ensemble data assimilation completed for HRRR over small Northeastern U.S. domain. David Dowell has been conducting off-line tests of storm-scale ensemble data assimilation configurations for the April 27, 2011 southeast severe weather outbreak case. This work has been coordinated with researchers at NSSL.

14.5.2.7 15 March 2015 **(NCEP)**
Establish routine verification of NCEP suite of convective weather guidance and begin design of calibration strategy for ensemble systems.

The new Verification 3.1.0 package was submitted to NCO for implementation in July. This package contains a correction to subtract the terrain height for cloud base height so that it is consistent with the observed height reports. Corrected cloud verification has been generated off-line. Verification 3.1.0 package was implemented on August 26th. The verification v3.1.19 package added HRRR verification and was implemented with the HRRR on September 30th. (Shafran, Zhou, Du, Yang)

Deliverables

14.5.2.E1 1 August 2014 (now planned for 30 Sept 2014) **(NCEP and ESRL)**
HRRRv1 implemented at NCEP pending available computing resources.

The 3-km HRRR was successfully implemented operationally at NCEP on 30 Sept. 2014, culminating several years of development, testing, and refinement, with long-term support by FAA/AWRP and NOAA operational modeling. Key collaborating organizations with GSD include NCEP/EMC, NCEP/NCO, and NCAR (WRF/ARW). HRRR forecasts are now being distributed to many different users by NOAA/NCEP, with reduced latency (1-h forecast by ~ +50 min., 15-h forecast by ~ +90 min.) and very near 100% reliability.

NCEP

HRRRV1 code continued to run in an NCO parallel during August. The official evaluation began on August 11, but it was restarted on August 15 due to the need to correct an issue with the analysis of 2-m dew points. The current target implementation date is September 30, and the HRRR was successfully implemented into operations on September 30th. (Manikin)

14.5.2.E2 1 April 2014 **(NCEP)**
Subject to NCEP Directors' approval, upgrades to HiResWindow and initial convection-allowing-scale ensemble (NSSE) becomes Operational at NCEP.

The HiResWindow version 6.0 upgrade package was implemented into NCEP Production on June 11th. Version 6.1 is being planned for FY15 and it will be connected to NCEP Convection-Allowing-Scale Ensemble (NCASE) run every 6 hours with guidance out to 36 hr including NAM-nest, HiResWindow members with some time-lagged members at least initially. (Pyle, DiMego, Zhou)

The HiResWindow version 6.0 upgrade package was implemented into NCEP Production on June 11th. (Pyle)

14.5.2.E3 1 April 2014 **(NCEP)**
With approval of NCEP Director, RTMAv6 upgrade package is implemented at NCEP.

The RTMA/URMA upgrade version 2.2.1 was implemented on January 28, 2014. (Manuel Pondeca, Steve Levine, Yanqiu Zhu, Ying Lin, Jeff Mcqueen, Geoff Manikin, Jim Purser, Dave Parrish, Yuqiu Zhu)

14.5.2.E4 15 July 2014 **(ESRL)**
Report on status of enhancements to HRRR for 2014 version, based on retrospective and real-time testing.

Mid-term assessment indicates overall good performance for 2014 HRRR (RAPv3/HRRRv2) compared to 2013 version. In particular, reduced (improved) bias for radar reflectivity is seen in 2014 HRRR compared to 2013. CSI scores are similar overall. More details can be found in the report at:
http://ruc.noaa.gov/pdf/HRRR_midterm_evaluation_2014.pdf

Testing and evaluation of RAPv3 / HRRRv2 system is ongoing to address a warm, dry bias seen in pre-frontal southerly flow areas (see subtask 14.5.2 for details).

14.5.2.E5 15 Oct 2014 **(ESRL)**
Complete 2014-summer evaluation with revised 3-km HRRR running every 1 h.

- Conduct real-time summer 2014 HRRR forecasts using 3-km WRF with 3-km assimilation initialized with radar-enhanced Rapid Refresh over full CONUS domain, monitor performance, modify code/scripts as needed, maintain high reliability working with ESRL computer facility
- Coordinate with other AWRP users and other collaborators, including coordination of HRRR grid transfers
- Provide project management
- Lead writing of report on summer 2014 HRRR experiments

- 2014 summer evaluation nearly complete, with good results and good HRRR reliability. Information collection and analysis ongoing toward creation of evaluation report.

14.5.2.E5.1 31 Mar 2015 **(ESRL)**
Report on convective weather forecast accuracy from HRRR by quarter for previous year.

14.5.2.E6 **request change to 20 Jan 2015** **(ESRL and NCEP)**
Based on real-time parallel and retrospective testing, HRRRv2 code finalized and ready for transfer to NCEP/EMC

ESRL

This date has been pushed back into Q2 (20 Jan 2015) but only in recognition that NCEP can't accept new HRRR code before then. Operational implementation of RAPv3 / HRRRv2 will be delayed to Q3/Q4 2015, due backlog of implementations scheduled following computer system upgrade planned early 2015 and to allow time for complete evaluation of changes within EMC test version. ESRL will continue evaluation of the HRRRv2 code until an expected transfer in January 2015. Changes from ongoing testing and evaluation of warm, dry bias will be incorporated into this code upgrade package along with upgrade to latest versions of GSI and WRF (v3.6.1). GSD has continued to evaluate HRRRv2 version during the real-time 2014 warm-season and is also working with computer specialists from NCEP to provide further optimization of the HRRR code for faster runtime on fewer computer cores.

NCEP

HRRRv1 must be implemented at NCEP before any transfer to EMC of the HRRRv2 code currently being tested at ESRL can be considered. The slip in the HRRRv1 implementation into September is consistent with the HRRRv2 code transfer pushback indicated above. (Manikin)

14.5.2.E7 15 Jan 2015 **(ESRL, assistance from CAPS under 5.1 support)**
Report on initial retrospective test of storm-scale ensemble data assimilation for small Northeast U.S. domain.
See subtask 14.5.2.6 for details on preliminary testing work in this area.

14.5.2.E8 31 Jan 2015 **(ESRL/GSD, NCEP)**
Pending NCEP computer readiness and EMC and NCEP initial recommendations, Requests for Change (RFCs) are filed to submit HRRR code changes as part of upgrade for HRRR v2 software to NCO.

NCEP
This work has not yet started pending implementation of HRRRv1. (Manikin)

ESRL

This work awaits final HRRRv1 operation implementation, completion of testing of changes for HRRRv2 at ESRL/GSD, and transfer of these changes to NCEP/EMC.

14.5.2.E9 1 Feb 2015 **(ESRL and NCEP)**
Provide revised 15-min RTMA surface analyses as improved alternative for frontal diagnostics and other diagnostics from surface analyses for CoSPA.

ESRL

This work awaits completion of testing of changes for HRRRv2 at ESRL/GSD, and transfer of these changes to NCEP/EMC.

NCEP

Work towards a 15-min RTMA must wait for a) completion of the HRRRv1 implementation in September, b) upgrade to RTMA/URMA in FY15Q2, and the upgrade to WCOSS Phase 2 computer. (Manuel Pondeca, Steve Levine, Jacob Carley, Jim Purser)

14.5.2.E10 15 March 2015 **(ESRL)**
Finalize all changes to the HRRR for the summer 2015 exercise into a frozen version of HRRR (and parent experimental RAP). This will include latest results on reflectivity verification.

Deliverables Task 2: Improve Quality Of Convective Weather Forecasts	Delivery Schedule
HRRRv1 implemented at NCEP pending available computing resources The 3-km HRRR was successfully implemented operationally at NCEP on 30 Sept. 2014, culminating several years of development, testing, and refinement, with long-term support by FAA/AWRP and NOAA operational modeling.	SEPT 2014 COMPLETE
B. Report status of enhancements to HRRR for 2014 version, based on retrospective and real-time testing. STATUS: Preliminary mid-summer report indicates 2014 HRRR improves upon the high bias seen in 2013, especially for longer forecasts. Testing of enhancements for warm, dry bias in RAP, HRRR ongoing. Report at**: http://ruc.noaa.gov/pdf/HRRR_midterm_evaluation_2014.pdf**	JUL 2014 COMPLETE
C. Complete 2014-summer evaluation with revised 3-km HRRR running every 1 h. Conduct real-time summer 2014 HRRR forecasts using 3-km WRF with 3-km assimilation initialized with radar-enhanced Rapid Refresh over full CONUS domain, monitor performance, modify code/scripts as needed, maintain high reliability working with ESRL computer facility Coordinate with other AWRP users and other collaborators, including coordination of HRRR grid transfers. Provide project management. Lead writing of report on summer 2014 HRRR experiments. STATUS: 2014 evaluation nearly complete, analysis ongoing toward report	OCT 2014
D. Based on real-time parallel and retrospective testing, HRRRv2 code finalized and ready for transfer to NCEP/EMC. (But not to be transferred until Jan 2015)	NOV 2014
E. Report on initial retrospective test of storm-scale ensemble data assimilation for small Northeast U.S. domain.	JAN 2015
F. Requests for Changes (RFCs) are filed to submit HRRR code changes as part of upgrade for HRRRv2 software to NCO.	JAN 2015
G. Provide revised 15-min RTMA surface analyses as improved alternative for frontal diagnostics and other diagnostics from surface analyses for CoSPA.	FEB 2015
H. Report on convective weather forecast accuracy from HRRR by quarter for previous year.	MAR 2015
I. Finalize all changes to the HRRR for the summer 2015 exercise into a frozen version of HRRR (and parent experimental RAP). This will include latest results on reflectivity verification.	MAR 2015

Task 3: Improve Quality Of Icing Weather Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE

Subtasks

14.5.3.1 1 Apr 2014 **(GSD, NCEP and NCAR/RAL)**
Begin initial testing of the current version of NCAR "aerosol-aware" microphysics in RAP and HRRR models. This will use a climatological aerosol distribution for cloud-condensation nuclei and ice nuclei initially.

GSD

The WRFv3.6+ version, upgraded to incorporate RAP / HRRR specific changes, is now running in the real-time RAP-dev3 cycle with the Thompson-Eidhammer aerosol microphysics activated. Although we don't have a fully controlled comparison with the WRFv3.5.1 aerosol unaware microphysics, we can summarize differences we have been seeing between dev3 and the dev2 and dev1 cycles running WRFv3.5.1 as follows. Bear in mind that these are real-time comparisons so don't include any mixed-phase or frozen precipitation events. During our evaluation we have been sharing our results with Greg Thompson.

- Precipitation is very similar overall, but with slightly better equitable threat scores at smaller precipitation amounts, slightly larger areas covered by light precipitation.

- Coverage of high cloudiness is notably less with the aerosol-aware scheme. This was the subject of some investigation to ensure we were properly initializing with the climatological water-friendly and ice-friendly aerosol fields intended to be used with the scheme. Once this was established, we concluded that part of the difference is explicable in terms of the depletion of ice-friendly aerosol at upper levels by ice nucleation during the first hour of the forecast.

- In conjunction with NCAR, we have been investigating a substantial difference in high-cloud coverage between the two schemes (old aerosol-unaware and new aerosol-aware Thompson schemes). Once it was established we were properly initializing the climatological water-friendly and ice-friendly aerosol fields intended to be used

with the scheme, we hypothesized that part of the difference could be explicable in terms of the depletion of ice-friendly aerosol at upper levels by ice nucleation as a result of our partial-cycling procedure. After sharing these results with the NCAR folks, they performed tests that provide strong evidence that the partial cycling procedure is not causing sufficient depletion to fundamentally affect coverage of high cloud; vertical advection of ice-friendly aerosol is more than sufficient to replenish depletion by ice nucleation. Rather, it appears that the current Thompson scheme, which uses the Cooper curve of ice nuclei concentration as a function of temperature, is implicitly assuming a higher ice nuclei concentration in the upper troposphere than is generally forecast by the aerosol-aware scheme.

- A notable beneficial impact of the scheme is that it contributes to reducing the surface warm/dry bias (see below under subtask 2). We think this is because in the aerosol-aware scheme, the interaction between radiation, aerosol and microphysics is done more accurately when the aerosol-aware scheme is used (thanks to efforts by Greg Thompson.)

- A concern is that the RAP forecast is taking about 12% longer to run on the Zeus supercomputer than does WRFv3.5.1 with the aerosol unaware microphysics using the same number of processors. We will not have comparable timing results on WCOSS until after RAPv3 and HRRRv2 code is transferred to NCEP.

Overall, we are encouraged by our evaluation thus far. However, more evaluation is needed, especially for cold-season weather conditions. Evaluation using winter retrospective cases is underway.

NCEP

EMC will await the results of GSD's effort before planning physics development in 2015 or beyond. (Ferrier, Aligo)

14.5.3.2 1 Apr 2014 **(GSD)**
Continue evaluation and modification of proposed RAPv3 physics suite in preparation for submission of code to NCEP, pending NCEP readiness, later in 2014.

An initial version of RAPv3 was indeed frozen in April for the summer-2014 HRRR-RAPv3 evaluation. However, extensive evaluation and development continued this quarter that will result in notable enhancement to RAPv3 before its transfer to NCEP now planned for November.

As mentioned under Task 1 above, an intensive effort, now largely completed, continued through much of this quarter toward alleviating the daytime warm / dry bias east of the Rockies that was discussed in more detail in last quarter's report. In doing this, we have looked at all aspects of the physics, not just at the PBL scheme, since it is typically problems in the interaction of the model representation of several coupled physical processes that strongly contribute to systematic forecast errors of this sort. There are several physics changes now in real-time and retrospective testing (RAP-dev3) that have produced an effective solution, some through better representing small cumulus clouds ("shallow convection"):

- Correcting a bug in the WRF model namelist in which the attenuation of solar radiation by (climatological) aerosol was inadvertently turned off. This had only a minor beneficial effect.
- Use of the aerosol-aware microphysics scheme.
- Miscellaneous changes to the MYNN surface and PBL schemes that have the effect of reducing slightly the surface heat flux and allowing for counter gradient heat flux near the top of the daytime mixed layer. These changes also reduced the warm and dry bias, but again only slightly (by < 0.5 deg C).
- Activating the "boundary-layer cloud' option in the MYNN PBL, and coupling the inferred cloud cover to the RRTMG radiation. This was a non-trivial exercise that required some tuning of the inferred cloud cover to obtain reasonable results.
- Activation and considerable revision to the Grell-Frietas shallow convection scheme, plus improving the coupling of parameterized shallow convection (Grell-Freitas) with short-wave radiation. Over the eastern half of the CONUS in areas of fair weather, shallow cumulus is common on most summer days. Prior to this summer's efforts, the radiation impacts of shallow cumulus had been ignored.
- A modification to the RUC LSM to prevent transpiration from being totally shut down once the wilting point is reached. In effect, soil moisture is added to maintain conditions near the wilting point. This has had a very beneficial effect over cropland and grassland areas over the central US.

The latter three changes are the most critical physics changes for removing the warm/dry bias. We are also considering possible changes to fixed fields that impact the behavior of the RUC LSM, based on published studies. A short retrospective period leading up to and surrounding the 17 June 2014 case in eastern Nebraska that exhibited particularly egregious behavior, leading to a bad HRRR forecast of convection, along with the use of the real-time RAP parallel cycles

not tied to the 2014 warm season evaluation were used in this effort, which involved several on the RAP development team, with primary contributions by Joe Olson, Tanya Smirnova and Georg Grell.

GSD is also now testing another new physics parameterization, using the Common Land Model (CLM, from NASA) lake component to give an improved estimate of lake surface temperatures. GSD is also using this lake model in the RAP-dev3 cycle running WRF3.6+. This lake model will likely be a component to RAPv4 and possibly to the NCEP-RAPv3 in testing this fall. Its use will likely improve near-surface conditions in the RAP and HRRR models in areas near small-size lakes (i.e., smaller than the size of the Great Lakes) for which we do not have good lake surface temperatures currently.

14.5.3.3 1 May 2014 **(GSD and NCAR/RAL)**
Begin efforts toward adding aerosol species or size categories as tracers to the RAPv3 and HRRR configurations of the WRF model, including surface sources, which are highly parameterized in the first version of the new microphysics scheme. Interact with WRF-Chem experts for aerosol source datasets, surface emission inventories, and translation of specific aerosol variables into the constituents needed by the microphysics scheme.

Discussions have started between GSD and NCAR about how to incorporate prognostic aerosol information from the RAP-Chem run into experimental versions of the RAP and HRRR.

14.5.3.4 1 May 2014 **(NCEP)**
Perform case-study simulations of high-impact weather events in order to evaluate NMMB model running the existing and newly added Thompson et al (2008) microphysics schemes.

A diagnostic tool was developed to plot vertical cross sections of any orientation, which also showed the underlying terrain. A different set of scripts was modified to make it easier to plot soundings directly from NEMSIO history files. Work with NCAR continued on coupling the Thompson microphysics with the RRTM v3 radiation in the regional NMMB. Thompson is currently reviewing the codes and trying to determine why some of his microphysics settings are not being used within the RRTM radiation codes. Code changes to the RRTM to speed up run times were tested and compiler-optimized code didn't give bit-identical results. Special tests were run to confirm that the results were still accurate even though not bit-identical. An updated version of the NMMB code was received that coupled the Thompson microphysics with the RRTMG radiation. Additional changes were made at NCEP and this final version was able to pass all of the regression tests using various physics options. These codes will be combined with changes to restructure and optimize the RRTMG before being committed to the NEMS repository. Information was provided to the DTC in preparation for their upcoming microphysics tests comparing the Thompson and Ferrier-Aligo microphysics. These tests will commence after these NMMB codes are in the NEMS repository. EMC will begin the NMMB case studies once all the remaining issues related to coupling the Thompson microphysics and RRTM radiation are resolved. (Ferrier, Aligo, Lin)

14.5.3.5 1 Jun 2014 **(NCAR/RAL)**
Test and evaluate the ice initiation mechanisms via aerosols to ensure the water-ice balance is relatively un-changed versus the prior scheme or else the updated scheme may result in significant loss of skill of aircraft icing forecasts since water is rapidly depleted by ice when too many ice crystals are supplied.

14.5.3.6 1 Sep 2014 **(NCAR/RAL)**
Continue to increase the complexity and interactions between the newly added aerosol variables in the microphysics with the PBL, radiation, convection, and shallow convection schemes. Particular focus will be the depletion of aerosols nucleated by sub-grid-scale eddies, the effects of which are represented by the PBL and convection schemes.

Current efforts: NCAR-RAL and NOAA-GSD are actively discussing possible ways to link the RAP-Chem output variables into the new aerosol-aware Thompson and Eidhammer (2014) microphysics scheme. T. Eidhammer has created a new aer_opt=3 to account for aerosol optical depth in the RRTMG scheme, which means the coupling between the same aerosols used in the new microphysics scheme is also being used by the shortwave radiation (for attenuation of incoming solar radiation by aerosols). This new option is currently under testing by P. Jimenez through leveraging with the DOE-WRF-Solar project. Initial testing appears positive, but further work is needed in the next two quarters. T. Eidhammer and G. Thompson are actively working together with J. Olson and J. Brown to resolve a possible issue of too few upper level ice clouds in the newest version of the scheme. A suite of sensitivity experiments has been designed and implemented for the 2011 Feb 16 case that was published in the literature and NCAR-RAL is actively diagnosing sensitivities with 0.1X, 1.0X, 10X number of ice-friendly aerosols as well as the older Cooper ice activation methods to determine an optimal solution in the RAP/HRRR models.

Future work: The ice initiation by aerosols code is being tested to resolve concerns of different upper level ice clouds as well as perform sensitivity analysis on the connections of aerosols, ice nucleation, clouds and precipitation. NCAR-RAL will assist NOAA-GSD to adopt/utilize the new scheme.

Problems encountered/Delays: None at this time.

Interface with other organizations: Various DOE Solar-WRF team members including GSD

Deliverables

(All Option A unless noted otherwise)

14.5.3.E1 1 Aug 2014 **(NCAR)**
Submit updated cloud microphysics code to WRF repository; document changes and purpose of changes in a report.

14.5.3.E2 31 Aug 2014 **(ESRL)**
Complete initial evaluation of aerosol-aware microphysics in RAP/HRRR test evaluation/demonstration at GSD for its suitability for future NCEP implementation.

14.5.3.E3 **request change to 15 Mar 2015** **(NCAR)**
Submit a report and possible journal manuscript related to the aerosol-ice sensitivity experiments including specific application to aircraft icing.

The text specifically mentions a report or journal paper by Dec 2014 regarding our work to test aerosol-ice nucleation (14.5.3.E3). We request a change to Mar 2015 for that item. It is NOT currently in the deliverable table itself, but we request a date change regardless. The work is currently being performed but will likely take longer than previously estimated. Thanks! --Greg

14.5.3.E4 20 Dec 2014 **(ESRL)**
At the annual NCEP Product Suite Review report on RAP / HRRR physics upgrades. This will include metrics on improvement to cloud and RH forecasts from these physics upgrades.

14.5.3.E4.1 31 Mar 2015 **(ESRL)**
Report on RH/cloud forecast accuracy from RAPv3 and HRRRv2 by quarter for previous year, related to icing guidance.

14.5.3.E5 31 Jan 2015 **(ESRL/GSD, NCEP)**
Pending NCEP computer readiness and EMC and NCEP initial recommendations, Requests for Change (RFCs) are filed to submit WRF physics code changes as part of upgrade for Rapid Refresh v3 software to NCO.

NCEP
This work has not yet started pending the HRRR implementation. (Manikin)

Deliverables Improve Quality Of Icing Weather Forecasts	Delivery Schedule
A. Complete initial evaluation of aerosol-aware microphysics in RAP/HRRR test evaluation/demonstration at GSD for its suitability for future NCEP implementation. ESRL/GSD: The aerosol-aware microphysics is now running and under evaluation in an experimental real-time RAP cycled run ("RAP-dev3"). See discussion under subtask 1.	AUG 2014 COMPLETE
B. At the annual NCEP Product Suite Review report on RAP/HRRR physics upgrades. This will include metrics on improvement to cloud and RH forecasts from these physics upgrades.	DEC 2014
C. Requests for Change (RFCs) are files to submit WRF physics code changes as part of upgrade for Rapid Refresh v3 software to NCO.	JAN 2015
D. Report on RH/cloud forecast accuracy from RAPv3 and HRRRv2 by quarter for previous year, related to icing guidance.	MAR 2015

Task 4: Develop Convection-ATM-Specific Improvements To Guidance From The HRRR (And Later, HRRRE) And Interact With CoSPA (Or Other) Program Partner Labs And The FAA

Subtasks

14.5.4.1 15 Aug 2014 **(GSD)**
Initial testing toward variational / ensemble cloud analysis scheme within the GSI framework.

Several meetings have been conducted between Ming Hu, Curtis Alexander and new GSD scientist, Terra Ladwig, to plan the first steps towards the variational/ensemble cloud analysis scheme within GSI. These meetings discussed details to handle processing of satellite (NESDIS and NASA Langley) cloud and radar precipitation hydrometeors in a new framework that will handle the mapping of these observations onto the analysis grid of any model background (RAP, NAM, GFS). Ming Hu will be updating the GSD GSI repository code to include recent commits to the EMC GSI repository and then Terra will add the GSI I/O capability for handling cloud-ice number concentration. Additional discussion took place regarding the creation of observation operators to map model cloud hydrometeors into observations of cloud base and cloud top heights for the variational minimization. Collaboration with NCAR was also discussed to obtain initial model background error covariance estimates for cloud and precipitation hydrometeors. Future planning was also discussed regarding use of the GFS ensemble including the partitioning of total water from the GFS into cloud water and ice and then how to merge analyzed cloud back to total water. Initial progress towards a variational/ensemble cloud analysis scheme will be presented at the AMS annual meeting in January 2015.

14.5.4.2 15 Nov 2014 **(GSD, NCEP)**
Finalize new cloud/hydrometeor analysis for 2015 RAPv3/HRRRv2

GSD

Modifications continue to the WRF-ARW version 3.6 codes including the creation of a total cloud field that combines explicit, parameterized and boundary layer clouds fields for a more accurate depiction of the modeled cloud field that includes unresolved scales. Initial plans have been made to improve the analysis of cloud ice information from satellite observations by incorporating both cloud ice mixing ratio and number concentration into the cloud analysis process for use by the Thompson microphysics scheme. Preliminary case study testing of full-column precipitating hydrometeor building in the HRRR cloud/hydrometeor analysis has been completed. This case study was followed by a retrospective experiment to build precipitation hydrometeors only at lower observed reflectivity thresholds below 28 dBZ. Results of this test indicate an improved 3-D analysis of precipitation and an increase in 1-hr accumulated precipitation at low thresholds. Additional tests will include application of the precipitating hydrometeor analysis during the sub-hourly assimilation/pre-forecast period in the HRRR along with full column cloud building.

NCEP

The DFI work done in 14.5.1.2 is related to this work. (Liu). 40-60 dBZ reflectivities from the 12-km parent (3-km CONUS nest) domain from the NAMRR were under (over) predicted when compared to observations. The vertical structure of reflectivity from the nested domain matched better against observations, and both results were expected because parameterized convection is called within the parent domain runs. Reflectivities from 4-km NMMB launcher runs produced similar results to the 3-km NAMRR nest runs. (Liu, Carley)

14.5.4.3 15 Feb. 2015 **(GSD, NCEP)**
Report on progress toward variational/ensemble cloud analysis

NCEP

The ability to have vertically varying localization for regional hybrid variational/ensemble analysis and several bug fixes on the cloud analysis was successfully added to the code repository in July. (Liu, Wu, Carley)

No activity in August. (Liu, Wu, Carley)

14.5.4.4 15 March 2015 **(NCEP, ESRL)**
Groups collaborate on initial work toward cloud analysis scheme for use in NARRE ensemble system.

NCEP

No activity in this quarter. (Liu, Wu, Carley)

14.5.4.5 31 March 2015 **(ESRL, NCEP)**
Establish routine verification of NCEP suite of ceiling & visibility guidance and begin design of calibration strategy for ensemble systems.

NCEP

The grid-to-grid (g2g) verification upgrade was documented and submitted to NCO for implementation. The g2g verification ran into problems verifying radar echo-top heights, because the values assigned to areas within the model domain where there is no radar reflectivity (e.g., clear sky conditions) were being incorrectly interpolated. A temporary short-term fix was devised. The database used by GSD for the High Impact Weather Prediction Project (HIWPP) verification was compared against the EMC verification database. HRRR forecasts of 1-km AGL reflectivity and echo-top height are being added to the g2g verification. Difficulties in converting the HRRR output into a grid that can be used by g2g, and different (from NCEP) HRRR echo-top height product IDs were worked. The new Verification 3.1.0 package was completed and implemented on August 26th. The full grid2grid package was modified to verify forecasts for a single model in GRIB2 format. The package was then used to produce verification statistics of forecast composite reflectivity and echo-top heights from NCO runs of the HRRR. This verification upgrade package was also implemented into operations on August 26th. The g2g verification site was updated (obs tables were removed and visibility and radar reflectivity were added for NAM nests and HRRR). Verification for the relocatable 1.33-km NAM fire weather nest was increased to 1-hr forecast intervals. The HRRR was added to the grid-to-obs verification, and bugs in the visibility and cloud height verification were fixed. The verification impacted by the bugs was corrected. (Zhou, Shafran, Du, Yang)

The full grid2grid package was modified to verify forecasts for a single model in GRIB2 format. The package was then used to produce verification statistics of forecast composite reflectivity and echo-top heights from NCO runs of the HRRR. The verification upgrade package was implemented into operations on August 26, and the results were evaluated to confirm the implementation was successful. (Zhou, Shafran, Du, Yang)

Deliverables

14.5.4.E1 1 April 2014 **(NCEP)**
With approval of NCEP Director, RTMAv6 upgrade package is implemented at NCEP (including visibility).

The RTMA/URMA upgrade version 2.2.1 was implemented on January 28, 2014, (Manuel Pondeca, Steve Levine, Yanqiu Zhu, Ying Lin, Jeff McQueen, Geoff Manikin, Jim Purser, Dave Parrish, Yuqiu Zhu)

14.5.4.E2 1 June 2014 **(NCEP)**
With approval of NCEP Director, SREF, HiResWindow and NAM upgrade packages are implemented at NCEP (including corrections to ceiling, visibility and cloud field prediction & diagnoses).

A blending of global ensemble and regional model IC perturbations has been constructed and tested for all SREF members in the new package. Diverse SREF physics schemes are being tested now. A draft plan was sent to ESRL to improve physics diversity in the NMMB and ARW members for the next SREF upgrade. A presentation was given to AWC on early verification of clouds in the newly implemented NAM. Diurnal issues were found with the AFWA and CLAVRx cloud analyses (compared to obs) and only seem to agree at 18Z. At 18Z the parent NAM has a slight low bias in cloud cover, possibly due to the lack of parameterized convection included in the RRTM radiation. Work began on a generalization of the NMMB preprocessing system (NPS) to allow for RUC LSM appropriate ICs, opening possibilities for land surface model diversity in the NMMB members of a future SREF system. (Du, Zhou, Yang, Jovic, Pyle, Rogers)

14.5.4.E3 15 Dec 2014 **(ESRL/GSD)**
Finalize cloud/hydrometeor assimilation for RAPv3 and transfer code to NCEP.

14.5.4.E4 15 Feb 2015 **(ESRL/GSD)**
Report on variational / ensemble/hybrid cloud analysis development for RAP and NARRE

14.5.4.E5 31 March 2015 **(NCEP)**
Subject to NCEP Directors' approval, upgrades to RTMA/URMA (addition of total cloud and cloud base height [ceiling]) become Operational at NCEP.

Total cloud amount and cloud ceiling analysis variables were added to the RTMA-GSI code. Several small bug fixes were added to the GSI to make the code less likely to fail. Work was done with a visiting U. Wisconsin/CIMMS collaborator on improving the RTMA's sky cover analysis. The assimilation of new GOES13 imager sky cover products was tested as a part of the RTMA analysis of total cloud amount. Capability was added to the RTMA to run tests using single observations of total cloud amount, and diagnostic utilities were developed to analyze raw, unformatted binary output directly from the GSI in order to more easily evaluate the RTMA analyses. The attempt to use GOES13 imager sky cover products for RTMA cloud amounts will need coordination with CIMSS. A script to create gridded time zones for the RTMA/URMA maximum and minimum temperature analysis was completed. A buddy-check QC algorithm within the GSI for RTMA was begun. Real time diagnostic RTMA and RTMA parallel webpages are being maintained. New developmental RTMA and

URMA systems that replace the RAP forecast with a blend of the HRRR and NAM-nest forecasts as the background and include an analysis of total cloud amount have been set up and are being evaluated. (Pondeca, Carley, Levine)

Deliverables Task 4: Develop Convection-ATM-Specific Improvements	Delivery Schedule
A. Report on ATM impact related to skill of HRRR forecast.	FEB 2015
B. Complete implementation of new microphysics scheme and associated reflectivity and ET diagnostics in real-time ESRL/GSD RAP and HRRR prior to code freeze for 2015-exercise release.	MAR 2015
C. Report on baseline testing of the early 2015 HRRR version.	MAR 2015
D. Report on evaluation of revised Thompson aerosol-aware microphysics for RAP/HRRR for its effects on echo-top and reflectivity in ESRL RAP/HRRR.	MAR 2015